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КОМПЛЕКСНЕ ОЦІНЮВАННЯ МІЖНАРОДНИХ РИЗИКІВ ПОСТАЧАННЯ НА ОСНОВІ КОМПОНЕНТНОГО ТА ІЄРАРХІЧНОГО ПІДХОДІВ

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Анотація. У статті здійснено аналіз міжнародних ризиків постачання, за результатами якого сформовано систему показників їх оцінювання та визначено відповідні складові. Визначення цих складових створює основу для систематизації відповідних показників і комплексного оцінювання ризиків за допомогою інтегрального показника. Виокремлення складових і показників оцінювання міжнародних ризиків постачання дало змогу побудувати дерево ризиків, структуроване за ієрархічним принципом. Перший рівень дерева представлений ключовими складовими міжнародних ризиків постачання, зокрема, економічними, організаційно-управлінськими, технологічними, логістичними, екологічно-соціальними та зовнішньополітичними. Економічна складова забезпечуватиме фінансову стійкість процесів постачання, організаційно-управлінська – ефективність управління через взаємодію з постачальниками, технологічна – процеси постачання через технологічне оснащення, автоматизацію і діджиталізацію, логістична – вчасність і надійність поставок, екологічно-соціальна – відповідність постачання міжнародним екологічним стандартам та зовнішньополітична – вплив факторів зовнішнього середовища на процеси постачання. Другий рівень сформовано у вигляді системи показників, які деталізують кожну зі складових і забезпечують можливість їх кількісного вимірювання. На основі запропонованого ієрархічного підходу розроблено інтегральний показник оцінювання міжнародних ризиків постачання, що дозволяє комплексно оцінити їхній рівень і врахувати вплив різноспрямованих факторів. Запропонований підхід сприяє підвищенню обґрунтованості управлінських рішень у сфері міжнародної логістики та постачання. Його практичне застосування дозволяє підприємствам своєчасно ідентифікувати критичні ризики та мінімізувати їхній вплив на результати діяльності. Крім того, використання інтегрального показника забезпечує можливість порівняльного аналізу ризиків у динаміці та між різними підприємствами або ринками. Отримані результати можуть бути використані як основа для формування стратегій управління ризиками в умовах глобалізаційних викликів і нестабільності зовнішнього середовища.

Ключові слова: економічна, організаційно-управлінська, технологічна, логістична, екологічно-соціальна, зовнішньополітична складові міжнародних ризиків постачання, дерево ризиків, інтегральний показник оцінювання.

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COMPREHENSIVE ASSESSMENT OF INTERNATIONAL SUPPLY RISKS BASED ON COMPONENT AND HIERARCHICAL APPROACHES

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Abstract. The article analyzes international supply risks and proposes a system of indicators for their assessment by identifying the key components that shape these risks. The identification of these components provides a conceptual basis for the systematization of relevant indicators and enables a comprehensive risk assessment using an integrated indicator. Furthermore, the identified components and assessment indicators facilitated the development of a hierarchical risk tree. At the first level, the risk tree comprises the principal components of international supply risks: economic, organizational and managerial, technological, logistical, environmental and social, and geopolitical. The economic component ensures the financial stability of supply processes; the organizational and managerial component reflects the effectiveness of management through interaction with suppliers; the technological component characterizes supply processes in terms of technological equipment, automation, and digitalization; the logistical component determines the timeliness and reliability of deliveries; the environmental and social component reflects compliance with international environmental standards; and the geopolitical component captures the influence of external environmental factors on supply processes. The second level is formed as a system of indicators that detail each component and enable their quantitative measurement. Based on the proposed hierarchical approach, an integral indicator for assessing international supply risks has been developed, allowing for a comprehensive evaluation of their level and consideration of the impact of diverse factors. The proposed approach contributes to improving the validity of managerial decision-making in the field of international logistics and supply. Its practical application enables enterprises to timely identify critical risks and minimize their impact on performance. In addition, the use of the integral indicator provides opportunities for comparative analysis of risks over time and across different enterprises or markets. The obtained results can serve as a basis for developing risk management strategies under conditions of globalization challenges and environmental instability.

Keywords: economic, organizational and managerial, technological, logistical, environmental and social, geopolitical components of international supply risks; risk tree; integral assessment indicator.

Introduction. The international supply process is characterized by numerous risks arising from the instability of the external environment, the challenges of globalization, changing trade conditions, and the need to coordinate activities among multiple participants in

global supply chains. To ensure the efficiency and reliability of assessing international supply risks of enterprises under globalization challenges, it is advisable to identify key components that reflect the nature of such assessment. The determination of these components creates a basis for the systematization of relevant indicators and comprehensive risk assessment using an integral indicator.

The findings reported by Lymar [1] provide a basis for identifying the following risks within the international supply process: logistical, financial, environmental, social, transport, operational, technical, reputational, and others. To ensure effective supply risk management, the author proposed tools for their implementation and expected outcomes under the imperatives of sustainable development.

Ruda M. [5] studies the circular supply chain, which is based on resource recovery and reuse, with particular attention focused on the environmental and social components, the quality of which determines the economic component of the supply chain.

The study by Shcherbyna V. [8] presents the environmental, economic, and social components of logistics, on the basis of which the integral index of cold logistics efficiency is calculated. Within the identified components, the author calculates the following indicators: profitability of logistics operations, level of product losses, investment efficiency, level of service quality, personnel qualification and injury rate, the coefficient of packaging reuse, and fleet energy efficiency, among others. Thus, as a result of the performed calculations, five levels of cold logistics efficiency were identified (low, medium, sufficient, high, and very high). Their determination at enterprises makes it possible to assess the current level of efficiency and identify the corresponding category.

The study by Aspeteg J. [9] demonstrates the resilience of the supply chain in the defence industry, taking into account demand and supply risks (internal and external). Busse C. [10] presents the types of risks in the supply chain and methods for their identification; Jiang H. [11] emphasizes the need to establish risk management committees, as they contribute to the efficiency of corporate investments. In turn, Yin H. [13] studied economic risks through the theory of the COSO risk management process.

Thus, scientific studies consider various approaches to supply risk management; however, there is no comprehensive system for their quantitative assessment. This necessitates the development of an integrated methodological approach to assessing international supply risks. Developing such a system will ensure more informed managerial decision-making and enhance enterprises' adaptability to external challenges. In addition, the integral assessment will contribute to increasing the transparency of supply processes and aligning them with the principles of sustainable development.

Task Statement. The purpose of this study is to identify the components and indicators of international supply risks, based on which an integral assessment of the effectiveness of international supply risk management can be carried out. The study is aimed at forming a system of indicators that most comprehensively reflect the supply process under globalization challenges, as well as at their structuring according to the relevant components.

Results. Within the framework of a comprehensive assessment of international supply risks of enterprises, we propose to identify the following components: economic, organizational and managerial, technological, logistical, environmental and social, and geopolitical. The components and indicators for assessing international supply risks of enterprises under globalization challenges can be graphically represented using an indicator tree (Fig. 1). The economic component ensures the financial stability of supply processes, financial resource efficiency (cost reduction), and reflects the level of enterprise dependence on suppliers or specific resources.

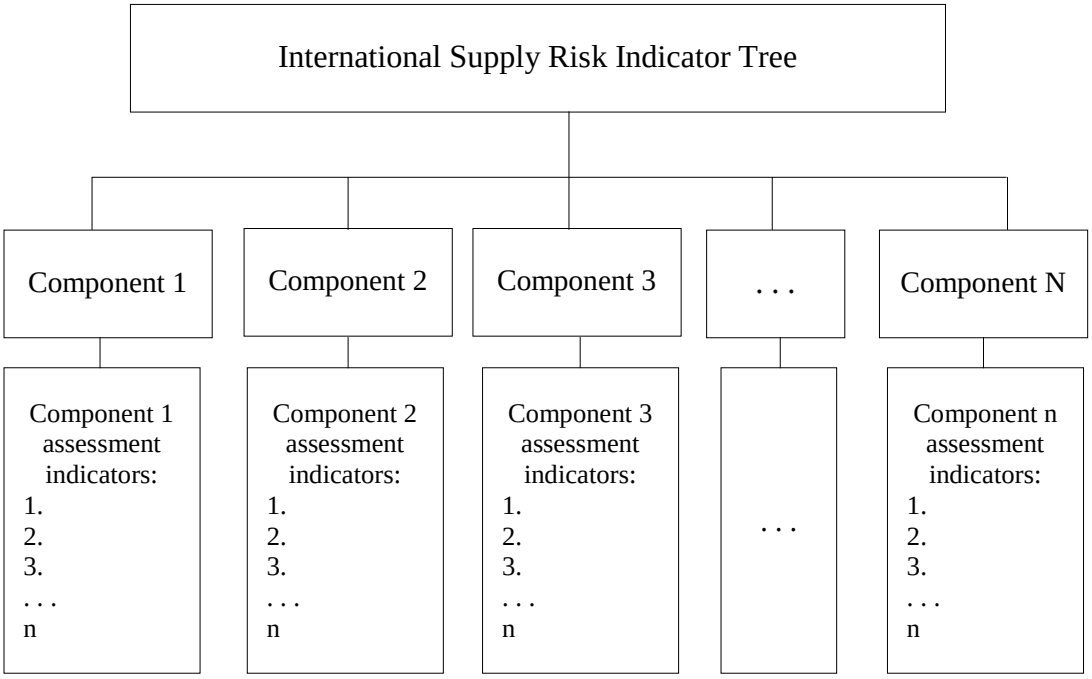

Fig. 1. International Supply Risk Indicator Tree of enterprises in the context of globalization challenges

(Notation: N – the number of component indicators of international supply risks; n – the number of indicators of international supply risks).

Source: author's own development.

The organizational and managerial component ensures the effectiveness of management through interaction with suppliers and forms the quality of relationships with partners, etc. The technological component ensures supply processes through technological equipment, automation, digitalization, and the reliability of information systems in order to establish partnership relations in the field of international supply. The logistical component ensures the timeliness of deliveries, reliability of routes, and the level of losses or delays in the international supply process.

The environmental and social component ensures compliance of supply processes with international environmental standards, the level of social responsibility of suppliers, as well as the impact of logistics and production processes on the environment and society. The geopolitical component reflects the influence of external environment factors on supply processes and also demonstrates the stability of partner countries, trade restrictions, sanctions, and other external risks.

The formation of components involves the development of a system of indicators for assessing international supply risks of enterprises under globalization challenges. The set of defined components and indicators will serve as the basis for forming an integral indicator for assessing international supply risks of enterprises. This, in turn, will act as a key tool for determining the level of risks and substantiating measures for their prevention and minimization.

The economic component includes the following indicators [3, 8]:

- share of lost customers (%);
- resource dependence;
- share of logistics costs (%);

- level of financial dependence on one supplier (%);
- exchange rate risk changes (for import supplies).

Share of lost customers (I_{zv}) – shows the loss of customers due to problems in the supply process, in particular due to delays or non-compliance with cooperation terms.

$$I_{zv} = {}^{Z_v}/_{Z_z} * 100\ \%, \quad (1)$$

where Z_v – number of lost customers; Z_z – total number of customers.

Resource dependence (R_z) – shows the level of enterprise dependence on suppliers or specific resources, which may affect changes in cooperation conditions.

$$R_z = {}^{Q_r}/_{Q_z}, \quad (2)$$

where Q_r – volume of resources from one supplier**;** Q_z – the total volume of resources received by the enterprise. The indicators can be measured in physical units (tons, kg) and monetary units (UAH, USD, EUR).

If R_z is equal to 1, then the dependence is very high;

$R_z <$ 0,3-0,4, allowed level of dependency;

$R_z \approx$ 0,5, potential risk of supplier dependency.

In addition, resource dependence can be calculated using the Herfindahl-Hirschman index due to supplier concentration [7]:

$$R_z = \sum_{i=1}^{n} S_i^2, \quad (3)$$

where S_i – each supplier's share in the enterprise; *n* – total number of suppliers in the enterprise; *i* –serial number of suppliers.

Share of logistics costs (L_v) – shows the efficiency of an enterprise in the supply process through the level of costs for transportation, storage, and support of material flows within the overall cost structure, as well as reflects the rationality of logistics process organization and the degree of influence of logistics risks on enterprise activities.

$$L_v = {}^{V_s}/_{V_z} * 100\ \%, \quad (4)$$

where V_s – total logistics costs of the enterprise.; V_z – total company expenses.

Level of financial dependence on one supplier (F_z) – shows the share of financial costs attributable to one supplier and reflects the risk of enterprise dependence on cooperation conditions, pricing policy, or a single reliable supplier.

$$F_z = {}^{C_o}/_{C_z}, \quad (5)$$

where C_o is the amount of expenses from one supplier; Cz is the total purchasing costs from all suppliers in the enterprise.

Exchange rate risk changes (for import supplies) (K_p) – shows the level of influence of exchange rate fluctuations on the cost of imported purchases, as well as the degree of financial instability of the enterprise's expenses due to changes in the currency environment.

$$K_p = {}^{K_t - K_0}/_{K_0} * 100\ \%, \quad (6)$$

where K_t – exchange rate at the time of calculation.; K_0 – exchange rate at the time of conclusion of the contract. The change in exchange rate risks is determined as the relative deviation of the exchange rate or the actual costs of import supplies from their planned value and reflects the sensitivity of enterprise costs to currency fluctuations.

The organizational and managerial component includes the following indicators [8]:

- number of contract violations (%);
- average time for agreeing on changes in orders;

- frequency of supplier changes.

Number of contract violations (Q_k) – shows the level of unreliability and discipline in the fulfillment of contractual obligations by suppliers, as well as reflects the frequency of deviations from the agreed cooperation terms (delivery deadlines, volumes, quality, etc.), which may indicate an increased risk in the enterprise's supply system.

$$Q_k = {}^{Q_p}\!/_{Q_{zag}} * 100\ \%, \tag{7}$$

where Q_p – number of violations recorded in the supply process; Q_{zag} – total number of deliveries.

Average time for agreeing on changes in orders (T_s) – shows the efficiency and effectiveness of the enterprise's interaction with suppliers in the process of making changes to the terms of the order, and also reflects the flexibility of the supply system and the ability to quickly respond to internal and external changes.

$$T_s = {}^{\sum_{i=1}^{n} t_i}\!/_{n}, \tag{8}$$

where t_i – time to agree on changes for each delivery, n – total number of changes made.

Frequency of supplier changes (S_z) – shows the level of stability of the company's supplier base, as well as the intensity of supplier rotation, which may indicate the presence of risks in cooperation (unreliability, change of conditions, search for more profitable alternatives).

$$S_z = {}^{N_{zm}}\!/_{N_{zag}}, \tag{9}$$

where N_{zm} – number of supplier changes over a certain period; N_{zag} – total number of suppliers.

The technological component includes the following indicators [3]:

- the level of automation of supply processes;
- the compatibility of IT systems with suppliers;
- the level of cyber risks in the supply chain;
- the level of use of ERP/SCM systems.

The level of automation of supply processes (R_a) – shows the level of application of information technologies and digital systems in the performance of supply operations, which contributes to increasing the speed, accuracy and efficiency of logistics process management:

$$R_a = {}^{N_a}\!/_{N_t}, \tag{10}$$

where N_a – number of automated supply processes; N_t – total number of supply processes.

The compatibility of IT systems with suppliers (S_p) shows the level of technical and functional consistency of the enterprise's information systems with suppliers' digital platforms, which ensures effective data exchange, integration of business processes and continuity of interaction in supply chains.

$$S_p = {}^{N_{int}}\!/_{N_{zag}}, \tag{11}$$

where N_{int} – number of suppliers with whom automated supply processes have been agreed; N_{zag} – total number of suppliers.

The level of cyber risks in the supply chain (R_k) – shows the likelihood and potential impact of cyber threats (hacks, data leaks, cyberattacks, IT system failures) on the functioning

of the supply chain, which can lead to information security breaches, supply disruptions and financial losses.

$$R_k = P * I, \quad (12)$$

where P – probability of occurrence; I – probability of occurrence.

The level of use of ERP/SCM systems (R_{ERP}) shows the level of implementation and intensity of use of corporate information systems for enterprise resource management (ERP) and supply chain management (SCM), which ensure the integration of business processes, automation of operations and increased efficiency of supply management.

$$R_{ERC} = {}^{N_{ERP}}/_{N_{total}}, \quad (13)$$

where N_{ERC} – number of processes supported by ERP/SCM; N_{total} - total number of processes

The logistics component includes the following indicators [1, 5, 8]:

- average delivery time;
- share of delivery delays (%);
- reliability of transport routes;
- influence of geopolitical factors on routes.

The average delivery time (T_d) characterizes the speed and efficiency of logistics operations, reflecting the effectiveness of transportation management and order fulfilment processes.

$$T_d = {}^{\sum_{1=j}^{i} t_{dos}}/_{K_z}, \quad (14)$$

where t_{dos} – the sum of the delivery time of all orders; K_z – number of delivered orders.

Share of delivery delays (P_z) characterizes the level of unreliability and instability of delivery performance, i.e. the frequency of cases when deliveries are made later than planned.

$$P_z = {}^{P_{zt}}/_{Q_{zag}}, \quad (15)$$

where P_{zt} – number of recorded delayed deliveries; Q_{zag} – total number of deliveries.

Reliability of transport routes (M_n) characterizes the stability and predictability of cargo delivery along specified routes, i.e. the ability to ensure timely, safe and uninterrupted transportation without delays, failures or losses.

$$M_n = {}^{P_v}/_{Q_{zag}}, \quad (16)$$

where P_v – number of deliveries completed on time; Q_{zag} – total number of deliveries.

Influence of geopolitical factors on routes (F_g) – characterizes the level of dependence of transport and logistics routes on the political situation in the world, in particular international relations, conflicts, sanctions, customs policy and regulatory restrictions.

$$F_g = {}^{Q_{zm}}/_{Q_{zg}}, \quad (17)$$

where Q_{zm} – number of routes that have undergone changes; Q_{zg} – total number of routes.

The environmental and social component includes the following indicators [2, 12]:

- the level of CO_2 emissions in the supply chain;
- the share of environmental certificates (ISO 14001, etc.);
- compliance with social standards (labor, human rights).

The level of CO_2 emissions in the supply chain – shows the total amount of greenhouse gases (in terms of CO_2) generated at all stages of the movement of goods: from production and storage to transportation and delivery to the end consumer [2].

The share of environmental certificates (E_s) characterizes the level of implementation of environmental management systems in the company or among its suppliers, as well as the degree of compliance of activities with international environmental standards.

$$E_s = {}^{N_s}\!/_{N_g} * 100\%, \tag{18}$$

where N_s – number of certified partners and suppliers; N_g – total number of partners and suppliers.

Compliance with social standards (D_s) – characterizes the level of ensuring socially responsible behavior of the enterprise and its partners in the supply chain, in particular, compliance with labor rights, safe working conditions, principles of non-discrimination and protection of human rights [12]. It is advisable to calculate the indicator on an expert scale:

1) 0-0.2 - low level of compliance with social standards;
2) 0.21-0.5 - medium level of compliance with social standards;
3) 0.51-1 - high level of compliance with social standards.

The foreign policy component includes the following indicators [6]:

- level of political risk of the supplier country;
- impact of sanctions;
- stability of trade relations;
- dependence on imports of critical resources.

Level of political risk of the supplier country (R_{pr}) characterizes the level of influence of the political situation in the country of the supplier's location on the stability, continuity and reliability of the supply chain. It is advisable to calculate the indicator on an expert scale: 0-0.2 - low political risk; 0.21-0.5 - medium risk; 0.51-1 - high risk.

Stability of trade relations (V_s) characterizes the level of reliability and predictability of economic and trade relations between the enterprise and partner countries or suppliers, as well as the ability to ensure the continuity of international operations.

$$V_s = {}^{K_v}\!/_{K_g}, \tag{19}$$

where K_v – number of consistently executed trade contracts; K_g – total number of contracts.

Dependence on imports of critical resources (R_{iz}) characterizes the level of vulnerability of an enterprise or supply chain due to the need to use resources that come from external markets and have limited sources of supply

$$R_{iz} = {}^{N_{ik}}\!/_{N_{vk}}, \tag{20}$$

where N_{ik} – volume of imported critical resources; N_{vk} – total critical resources used.

The identification of components and indicators for assessing international supply risks made it possible to build a risk tree structured according to a hierarchical principle (Fig. 2). The first level of the tree is represented by the key components of international supply risks, in particular: economic, organizational and managerial, technological, logistical, environmental and social, and foreign policy. The second level is formed in the form of a system of indicators that detail each of the components and provide the possibility of their quantitative measurement.

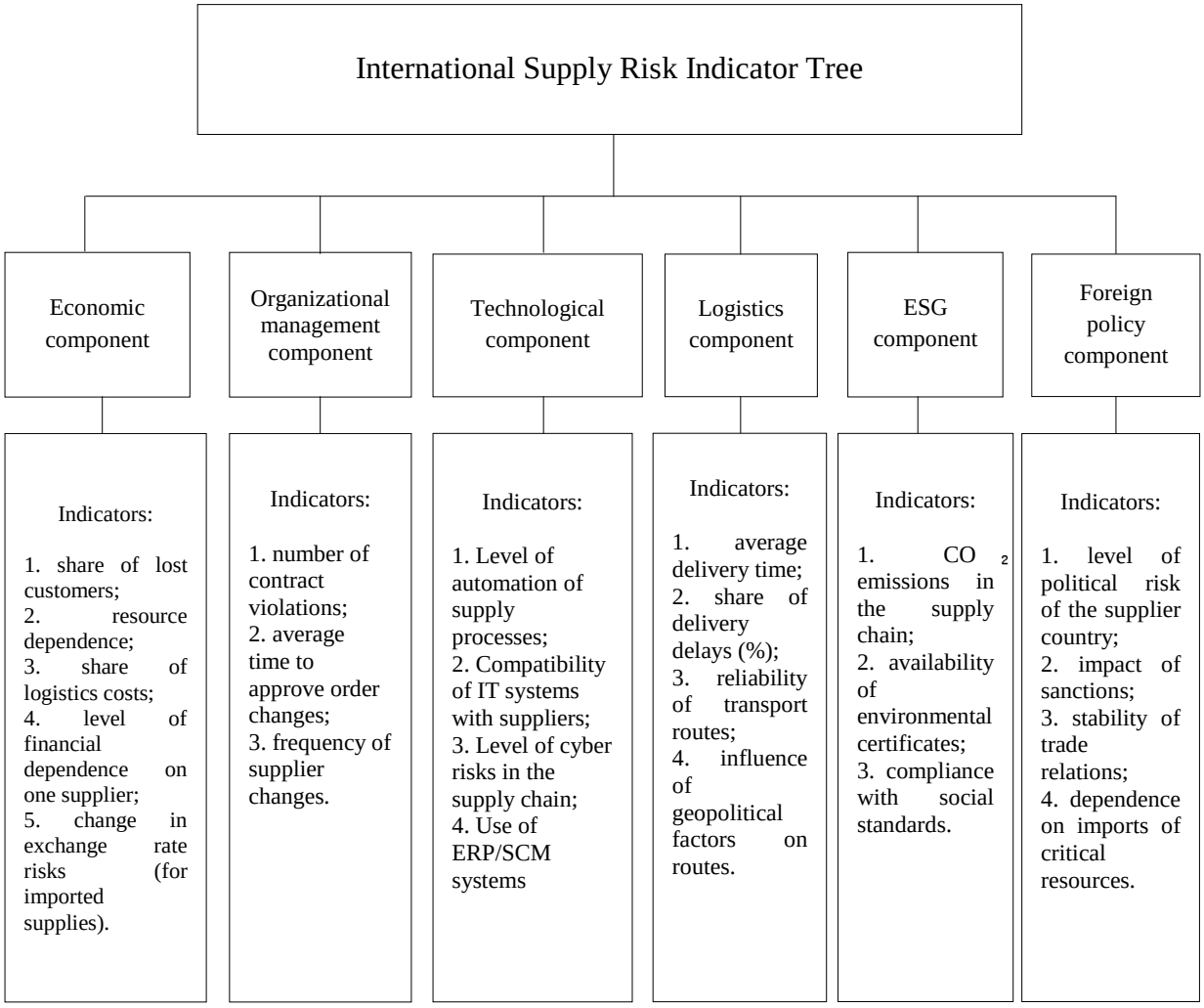

Fig. 2. Tree of indicators of international supply risks of enterprises in the context of globalization challenges

Source: author's own development.

According to the proposed tree of indicators of international supply risks, it is relevant to form an integral indicator of supply risk assessment. Thus, the integral indicator of international supply risk assessment (I_{RP}) will consist of 6 components, namely: economic (E_s), organizational and managerial (O_s), technological (T_s), logistical (L_s), environmental and social (S_s) and foreign policy (Z_s):

$$I_{RP} = E_s * w_1 + O_s * w_2 + T_s * w_3 + L_s * w_4 + S_s * w_5 + Z_s * w_6, \quad (21)$$

where w – weighting factor of a specific component.

To increase the reliability and accuracy of the assessment results for the integrated supply risk indicator, it is necessary to determine weighting factors that reflect the relative importance of individual risk factors and their impact on the overall risk level [4]. Such factors make it possible to ensure the objectivity of the assessment, take into account the specifics of the supply system under study, and increase the validity of management decisions.

Conclusions. The proposed integrated indicator allows for the generalization of the impact of heterogeneous factors and provides the possibility of a comparative analysis of the

level of risks between enterprises. The practical application of the developed approach will contribute to increasing the efficiency of supply chain management in conditions of uncertainty and globalization challenges. The proposed assessment system creates the basis for the timely identification of critical risk areas and the formation of preventive measures to minimize them. Its use ensures comprehensive consideration of economic, technological, logistical, environmental, and foreign policy factors that affect the stability of international supply chains. Prospects for further research lie in improving methods for weighted evaluation of indicators and adapting the model to the industry specifics of enterprises.

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